https://dx.doi.org/10.4314/dujopas.v10i2c.18
ISSN (Print): 2476-8316
ISSN (Online): 2635-3490

Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 10 No. 2c June 2024*

Morpho-Physiological Assessment of Some Rice (Oryza Sativa L.) Genotypes for Salinity Stress Tolerance

Bashir Mohammed Mayaki[1]*, Lawan Abdu Sani[1], Usman Abubakar[1], Jibril Sani Mohammed[2], Nuraddeen Mohammed[1], Rukayya Kabir Mato[1]

[1]Department of Plant Biology
Bayero University Kano,
Nigeria.

[2]Department of Biological Sciences,
Federal University Dutse,
Nigeria.

Email: mayakibashir@gmail.com

Abstract

Salinity is an ever increasing problem that reduces rice yield in rice producing areas. The rice plant is salt sensitive and its productivity is severely affected by the accumulation of soluble salts in soils. The arid and semi-arid zone of Nigeria where irrigation practices are widely adapted faces the most serious ecological and environmental problems arising from high saline soil conditions. Identification of salt tolerant rice genotype is one of the solutions to the problem of salinity. This study was conducted under a controlled environment at the Department of Plant Biology, Bayero University Kano, to evaluate the responses of six rice genotypes at four levels of NaCl concentrations (0 dS/m, 4 dS/m, 8 dS/m and 10 dS/m). Data were collected on (plant height, leaf chlorophyll content, shoot fresh and dry weight, root fresh and dry weight) and were subjected to analysis of variance for mean comparison. The results of analysis of variance revealed that the parameters measured were significantly ($p \leq 0.05$) affected for all varieties at different concentrations except at (0 dS/m) which is the control. The most effect was observed particularly in the range of 8 to 10 dS/m. Based on the IRRI modified standard evaluation system for rice salinity tolerance FARO 57, FARO 62, SUFI and FARAR ZAIRA were classified as susceptible varieties while FARO 44 and FARO 67 were classified as moderately tolerant varieties.

Keywords: Electrical Conductivity, Irrigation, Rice, Salinity, Sodium Chloride.

INTRODUCTION

Saline soil condition is a common abiotic stress that reduces productivity in many rice producing areas (Liu *et al*., 2019). The production of rice being a salt sensitive crop is considerably affected by salinity, which has been recognized as the second most widespread soil problem in rice growing countries, after drought (Uyoh *et al*., 2019). Rice-growing countries, both in the tropics and the temperate regions, are facing high soil salinity as a major problem which is more severe in the arid, semiarid, and coastal rice-producing areas of the tropics (Kargbo *et al*., 2019).

The extent of sensitivity to salt stress in rice plant varies upon the plant growth stage with most cultivars recording more damage at germination, early seedling stage, indicating that

Author for Correspondence

salinity has negative effect on the plant early growth stages (Zafar *et al*., 2015). It also affects the, plant growth, development, root index, root length shoot length and ultimately productivity. Salt-affected soils have much accumulation of complex combination of soluble salts. However, NaCl is considered the main cause of soil salinization, because of its abundance in many affected soils and its high solubility (Almeida *et al*., 2016).

The effect of high salinity on plant can be detected at the whole plant level in terms of decline in productivity and ultimately plant death (Parida *et al*., 2004). According to a global projection salt-affected soils are reported to be rising particularly in irrigated areas from 20 % (45 million hectares) to 33 % (74.25 million hectares) in the last decades (Kumar and Shrivastava, 2015). The increase recorded in the number of irrigated areas suggested that at a global scale, an area of about 2000 ha of irrigated cropland is affected by varying levels of salinity daily (Qadir *et al*., 2014). Jamil *et al*. (2011) reported that it has been estimated that more than 50 % of the arable land would be salinized by the year 2050. The main sources of salts include rainfall, mineral weathering, irrigation and various saline water bodies, underground water which redistributes accumulated salts during evaporation, chemical fertilizers applications, and man activities (James, 2018).

Therefore, understanding the perceptions of soil salinity, its effects on crop productivity and identifying varieties that are able to thrive under such condition is important in the development of the promising cultivars that addresses the needs of farmers. This study aimed to evaluate the growth responses of some rice genotypes under various level of salinity stress using some morpho-physiological parameters, to screen and identify salinity tolerant and susceptible rice varieties using pot screening experiment.

MATERIALS AND METHODS

Study Area: The experiment was conducted in a screen house at the Department of Plant Biology, Faculty of Life Science, Bayero University Kano old campus, located at latitude 11˚58^1 North and longitude 8˚ 30^1 East, and Centre for Dry Land Agriculture, Bayero University Kano.

Treatment Combination: Six (6) rice varieties; FARO57, FARO62, FARO44, FARO67, SUFI and FARAR ZAIRA were tested at different NaCl concentrations at the seedling stage to maturity under controlled conditions in the screen house replicated 3 times at the rates of 0, 6, 12 and 14 g per pot to obtain the salinity levels of 0, 4, 8, 10 dS/m, respectively in 5kg soil. The study adopted the procedure described by Senanayakee *et al*., (2017). Seedlings were thinned to three per pot containing a homogeneous mixture of planting medium including soil, farm yard manure. Seedlings were watered with tap water for 21 days. Thereafter, salinity treatment was applied. The control pots were irrigated with tap water throughout the period of the experiment. The treatments including the control were replicated three times with a spacing of 15cm and arranged in a completely randomized design.

Data Collection: The characters (plant height, and leaf chlorophyll content) were measured at four weeks interval from the first day after salinity application to 12weeks. Plants were then removed from pots and the roots were washed with tap water, the roots and shoots were separated and weighed for fresh weight. The plant shoots and roots were later dried at 70˚C for 48 hours in an oven and dry weight (g plant-1) was determined (James, 2017). International Rice Research Institute (IRRI) standard protocol (Gregorio *et al*., 1997) was used to assess the tolerance of the rice genotypes to salinity conditions.

Statistical Analysis: The differences between genotypes for the recorded characters were tested for significance using analysis of variance (ANOVA). Data collected were subjected to Genstat Statistical software package (Version 17.1.0.13780) for analysis of variance (ANOVA). The means were compared using least significance different test at 5% level of significance.

RESULTS

Physiochemical Properties

The soil and water used for the purpose of this study were analyzed prior to the commencement of the study to establish the level of electrical conductivity and the result is presented in Table 1a &b. The chemical and physical properties of the soil and water used for the purpose of this study was analyzed and presented in Table 1a & b. The initial electrical conductivity of the soil was 0.023 dS/m and the pH was 7.8 while that of the water used for irrigation was 7.3 and 0.027 dS/m respectively. All exchangeable cations recorded low values. Similarly, the exchangeable acidity (E.A) was low (0.334cmol/kg) while the cation exchange capacity was (27.165cmol/kg).The textural class of the soil used for this experiment was a sandy loamy soil.

Table 1a: Chemical Properties of Soil Used for this Study Chemical Properties of Soil

pH (H_20)	EC (dS/m)	P (mg/kg)	0.C (%)	N (%)	Ca (cmol/kg)	Mg (cmol/kg)	K (cmol/kg)	Na (cmol/kg)	E.A (cmol/kg)	CEC (cmol/kg)
7.88	0.023	17.116	0.798	0.175	4.565	0.887	0.212	19.138	0.334	27.165

Table 1b: Physical Properties of Soil Used for this Study Particle size distribution

Sand %	Clay %	Silt %	Textural class
66.64	18.08	15.28	Sandy Loam

Classification of Genotypes Based on IRRI Standard Evaluation System for Rice Salinity Tolerance

Based on the IRRI score for rice salinity tolerance, the varieties were categorized into four levels of stress response presented in Table 2. At 0dS/m all plants were scored 1 which indicated normal morphological growth and no salt stress symptoms, at 4 dS/m the varieties were scored 3 based on IRRI standard evaluation system, indicating nearly normal growth, but leaf tips or few leaves whitish or rolled . At 8 dS/m FARO 44 and 67 were scored 5 indicating retarded growth and most leaves rolling with just few elongated while FARO 62,57. SUFI and FARAR ZAIRA were scored 7 indicating completely cessation of growth with some plants dying. At 10 dS/m FARO 44 and 67 were scored 5 indicating retarded growth and most leaves rolling with just few elongated while FARO 62,57. SUFI and FARAR ZAIRA were scored 9 indicating all plants are dead or dying. On the basis of tolerance and susceptibility indices, FARO 44 and 67 were classified as moderately tolerant varieties, FARO 62 and 57 as susceptible varieties and SUFI and FARAR ZAIRA as highly susceptible varieties.

Table 2: Classification of Genotypes Based on IRRI Standard Evaluation System for Rice Salinity Tolerance

		Concentration			
Genotype	**0dS/m**	**4 dS/m**	**8 dS/m**	**10 dS/m**	**Tolerance**
FARO 62	1	3	7	9	Susceptible
FARO 44	1	3	5	5	Moderately Tolerant
FARO 67	1	3	5	5	Moderately Tolerant
FARO 57	1	3	7	9	Susceptible
SUFI	1	3	7	9	Highly Susceptible
FARAR ZAIRA	1	3	7	9	Highly Susceptible

Effect of Salinity on Plant Height of Some Rice (*Oryza sativa* L.) Varieties.

The main effect of salt concentration and varieties on plant height in rice is presented in Table 3. The results obtained indicated significant differences ($p \leq 0.05$) among the various treatments and genotypes studied at 4 weeks after salinity application. The highest plant height was observed at (4 dS/m) and the lowest plant height was recorded in plants treated with 10 dS/m. At 8 weeks after salinity application, plant height was significantly higher ($p \leq 0.05$) in the control plant (0 dS/m), compared to plants treated with 4 dS/m, 8 dS/m and 10 dS/m which recorded lower plant height with 10 dS/m recording the least plant height. Similar trend was observed at 14 weeks after salinity application with plant height being significantly higher in the control plants (0 dS/m) and significantly lower in plants treated with 10 dS/m compared to the control. The effect of variety was also significant ($p \leq 0.05$). At 4 weeks of stress imposition, FARO 44 (44.04) and FARO 67 (44.76) demonstrated a significantly higher plant height. At 8 weeks and 12weeks, FARO 67 consistently maintains significantly higher plant height, but plant height significantly decreased in FARO44 when stress was imposed at 12 weeks. The lowest plant height was recorded in the local varieties; SUFI and FARAR ZAIRA.

Table 3: Effect of Different Level of Salinity on Plant Height (cm) of Some Rice Varieties (*Oryza sativa* L.)

	WEEKS AFTER SALINITY APPLICATION		
TREATMENTS	4 WEEKS	8 WEEKS	12 WEEKS
0 dS/m	51.29^{a}	69.66^{a}	116.68^{a}
4 dS/m	40.69^{b}	55.95^{b}	96.73^{b}
8 dS/m	24.00^{c}	33.89^{c}	52.26^{c}
10 dS/m	11.51^{d}	14.90^{d}	20.91^{d}
LSD	0.901	1.691	2.781
VARIETIES			
FARO 62	29.11^{b}	45.46^{c}	79.68^{b}
FARO 44	44.04^{a}	55.50^{b}	65.48^{d}
FARO 67	44.76^{a}	59.46^{a}	100.91^{a}
FARO 57	29.98^{b}	44.19^{c}	72.93^{c}
SUFI	21.28^{c}	36.00^{d}	54.17^{e}
FARAR ZAIRA	22.08c	37.83^{d}	56.69^{e}
LSD	1.103	2.070	3.406
Trt. * Var	**	**	**

Figures followed by the same letters along the column are not significantly different according to Fisher's protected LSD at 5% level. WASA= Weeks after salinity application. **= Significant at 95% level. LSD= least significant difference, Trt= treatment, Var= varieties

Treatments and Varieties Interaction on Plant Heights (cm) at Weeks after Salinity Application.

The results from Table 4 describes the interaction effect of the selected genotypes and the various levels of salinity concentration on plant height. The result revealed that FARO 67 recorded the highest plant height at 0 dS/m (control). Although plant height varied greatly between the selected genotypes due to varietal differences, as salinity increases, plant height decreases significantly, while growth was completely arrested for most varieties at 10 dS/m, FARO 44 and FARO 67 recorded plant height of 36.63cm and 32.40 respectively at 4 weeks after salinity application. At 8 weeks after salinity application the results showed that the interaction between the genotypes and salinity was statistically significant ($P \leq 0.05$) as plant heights were reduced in all the genotypes compared to the control which recorded the highest plant height for all varieties, the least plant height were recorded in 10 dS/m with FARO 44 and FARO 67 having the best performance at this concentration while there were complete cessation of growth in FARO 62, FARO 57, SUFI and FARAR ZAIRA. Similar observation was recorded at 12 weeks after salinity application with plants grown under the control (0 dS/m)` treatment recording the highest plant height .The interaction effect between genotypes and varieties indicates significant differences ($P \leq 0.05$) as there was gradual reduction in plant height as the treatment concentration increases. The lowest plant height was observed in treatment 10 dS/m with FARO 44 and FARO 67 recording the highest plant height at this concentration.

Table 4: Treatments and Variety Interactions on Plant Heights(cm) at Weeks after Salinity Application.

		TREATMENTS			
	VARIETIES	0 dS/m	4 dS/m	8 dS/m	10dS/m
4 WASA	FARO 62	45.10^{d}	40.30^{e}	31.03^{gh}	0.00^{i}
	FARO 44	49.50^{c}	47.93^{c}	42.10^{e}	36.63^{f}
	FARO 67	58.07^{a}	47.83^{c}	40.73^{e}	32.40^{g}
	FARO 57	49.37^{c}	40.40^{e}	30.13^{gh}	0.00^{i}
	SUFI	49.97^{c}	35.13^{f}	0.00^{i}	0.00^{i}
	FARAR ZAIRA	55.77^{b}	32.57^{g}	0.00^{i}	0.00^{i}
8 WASA	FARO 62	69.83^{b}	61.83^{cd}	50.17^{ef}	0.00^{h}
	FARO 44	70.33^{b}	57.77^{d}	51.07^{e}	42.83^{g}
	FARO 67	76.20^{a}	62.40^{c}	52.69^{e}	46.57^{fg}
	FARO 57	69.27^{b}	58.07^{d}	49.43^{ef}	0.00^{h}
	SUFI	59.20^{cd}	44.80^{g}	0.00^{h}	0.00^{h}
	FARAR ZAIRA	73.10^{ab}	50.83^{e}	0.00^{h}	0.00^{h}
12 WASA	FARO 62	119.43^{bc}	110.53^{d}	88.77^{hi}	0.00^{m}
	FARO 44	84.70^{i}	66.41^{k}	58.60^{l}	52.23^{l}
	FARO 67	122.30^{b}	109.10^{de}	99.00^{fg}	73.23^{j}
	FARO 57	129.67^{a}	94.90^{gh}	67.17^{jk}	0.00^{m}
	SUFI	113.33^{cd}	103.33^{ef}	0.00^{m}	0.00^{m}
	FARAR ZAIRA	130.67^{a}	96.10^{g}	0.00^{m}	0.00^{m}

Figures followed by the same letters along the columns are not significantly different according to Fisher's protected LSD at 5% level. WASA= Weeks after salinity application

Effects of Different Level of Salinity on Chlorophyll Content of Some Rice Varieties (*Oryza sativa* L.)

The results for the effect of salinity and varieties on chlorophyll is presented in Table 5 and it indicates that among the various salinity treatment levels, the highest concentration of salinity (10 dS/m) recorded the lowest value of chlorophyll compared with control treatment (0 dS/m). At 8 weeks after salinity application there was significant difference ($P \leq 0.05$) among the various treatments. The highest chlorophyll was observed in control (0 dS/m) and the least chlorophyll was observed in the highest salinity treatment level (10 dS/m). Similarly, at 8 weeks after salinity application there was significant difference in the amount of chlorophyll obtained at the various treatment level, control treatment had the highest chlorophyll (40.67) while the least (8.29) was observed in 10 dS/m. At 12 weeks after salinity application, similar trend was observed with control having the highest chlorophyll content.

The effect of variety indicated that FARO 67 had the highest chlorophyll (16.43) than FARO 44, FARO 57, FARO 62, SUFI and FARAR ZAIRA which had the least chlorophyll of (8.70) at 4 weeks after salinity application. At 8 weeks after salinity application, chlorophyll was significantly higher in FARO 44 and FARO 67 with (33.55 and 32.99) respectively and lower in Sufi with (16.14). At 12 weeks after salinity application, FARO 67 and FARO 44 recorded significantly higher chlorophyll ($p \leq 0.05$) than FARO 62, FARO 57, SUFI and FARAR ZAIRA.

Table 5: Effect of Different Level of Salinity on Chlorophyll Content of Some Rice Varieties (*Oryza sativa* L.)

	WEEKS AFTER SALINITY APPLICATION		
TREATMENTS	4 WEEKS	8 WEEKS	12 WEEKS
0 dS/m	20.31[a]	40.67[a]	30.41[a]
4 dS/m	15.62[b]	32.67[b]	26.99[b]
8 dS/m	8.73[c]	20.02[c]	19.87[c]
10 dS/m	3.76[d]	8.29[d]	9.41[d]
LSD	0.701	1.055	0.872
VARIETIES			
FARO 62	11.15[d]	28.61[b]	24.65[b]
FARO 44	14.91[b]	33.55[a]	29.84[a]
FARO 67	16.43[a]	32.99[a]	29.92a
FARO 57	12.51[c]	24.79[c]	23.12[c]
SUFI	8.95[e]	16.14[d]	15.82[d]
FARAR ZAIRA	8.70[e]	16.39[d]	6.67[e]
LSD	0.858	1.292	1.069
Tr. * Var	**	**	**

Figures followed by the same letters along the columns are not significantly different according to Fisher's protected LSD at 5% level. WASA= Weeks after salinity application. **= Significant at 95% level. LSD= least significant difference, Trt= treatment, Var= varieties

Treatments and Varieties Interaction on Chlorophyll Content at Weeks after Salinity Application.

Variety × salt concentration is presented in Table 6. Interaction after 4 weeks of salt stress imposition showed that chlorophyll content was significant ($p \leq 0.05$) high in the control (0 dS/m) for FARO 44, FARO 67, FARO 57, SUFI and FARAR ZAIRA. Imposition of salt stress significantly reduced chlorophyll content in all the varieties. At 8 dS/m and 10 dS/m, the effect of the stress was significantly high ($p \leq 0.05$) and resulted in complete absence of chlorophyll for SUFI and FARAR ZAIRA. At 8 weeks after inducing salt stress, the result showed that chlorophyll was significantly high ($p \leq 0.05$) for FARO 62 and FARO 67 recording the highest mean value for chlorophyll with (44.79 and 43.08) respectively for the control experiment. However, imposition of the salt stress significantly ($p \leq 0.05$) reduced chlorophyll content in all the varieties, SUFI and FARAR ZAIRA recorded the lowest chlorophyll (0.00) at 8 dS/m and 10 dS/m indicating complete elimination of chlorophyll in these varieties. Similarly at 12 weeks after stress imposition, The mean of chlorophyll was significant ($p \leq 0.05$) high for FARO 62, FARO 57 and SUFI at 0dS/m, and the chlorophyll content was significantly reduced when the salt stress was imposed. Chlorophyll was completely absent in SUFI and FARAR ZAIRA when treated with 8dS/m and 10 dS/m.

Table 6: Treatments and Variety Interactions on Chlorophyll Content at Weeks after Salinity Application.

		TREATMENTS			
	VARIETIES	0 dS/m	4 dS/m	8 dS/m	10 dS/m
	FARO 62	18.35^{bc}	14.85^{fgh}	11.37^{k}	0.00^{l}
	FARO 44	19.85^{ab}	15.46^{ef}	13.22^{hi}	11.13^{k}
	FARO 67	21.53^{a}	18.04^{cd}	14.69^{fghi}	11.44^{jkk}
4 WASA	FARO 57	20.33^{a}	16.58^{de}	13.11^{ij}	0.00^{l}
	SUFI	20.70^{a}	15.08^{efg}	0.00^{l}	0.00^{l}
	FARAR ZAIRA	21.07^{a}	13.71^{ghi}	0.00^{l}	0.00^{l}
	FARO 62	44.79^{a}	37.12^{de}	32.54^{fg}	0.00^{k}
	FARO 44	40.90^{bc}	36.94^{de}	30.47^{gh}	25.89^{ij}
	FARO 67	43.08^{ab}	34.80^{ef}	30.23^{gh}	23.84^{j}
8 WASA	FARO 57	38.88^{cd}	33.43^{f}	26.86^{i}	0.00^{k}
	SUFI	36.55^{de}	28.00^{hi}	0.00^{k}	0.00^{k}
	FARAR ZAIRA	25.74^{ij}	25.74^{ij}	0.00^{k}	0.00^{k}
	FARO 62	35.27^{a}	32.63^{bcd}	30.70^{defg}	0.00^{l}
	FARO 44	31.06^{cdef}	28.09^{i}	31.24^{cde}	28.97^{fghi}
	FARO 67	32.90^{bc}	30.36^{efgh}	28.96^{fghi}	27.47^{i}
12 WASA	FARO 57	33.74^{ab}	30.44^{efg}	28.29^{hi}	0.00^{l}
	SUFI	34.58^{ab}	28.69^{ghi}	0.00^{l}	0.00^{l}
	FARAR ZAIRA	24.93^{j}	11.73^{k}	0.00^{l}	0.00^{l}

Figures followed by the same letters along the columns are not significantly different according to Fisher's protected LSD at 5% level. WASA= Weeks after salinity application

Effect of Different Levels of Salinity on Shoot and Root Fresh and Dry Weight of Some Rice Varieties (*Oryza sativa* L.)

Table 7 describes the main effect of salinity and varieties on shoot and root fresh and dry weight. The result obtained indicated significant differences ($P \leq 0.05$) on shoot fresh weight among the various treatment and genotypes. The result showed that shoot fresh weight was highest (339.29g) in the control 0 dS/m for all varieties and decreased significantly as the concentration of salinity increases, the lowest (36.22g) shoot fresh weight was recorded at 10 dS/m. With respect to the varieties, shoot fresh weight differed considerably, the highest shoot fresh weight was observed in FARO 67 (286.17g), and the lowest was observed in FARAR ZAIRA (102.29g). The result obtained from the estimation of the main effects of salinity and varieties on shoot dry weight showed significant ($P \leq 0.05$) difference among the various treatments and genotypes. The highest value (119.33g) was recorded in the control (0dS/m) treatment, while the lowest value (11.47g) was recorded in the highest salinity level (10dS/m). FARO 67 exhibited the highest shoot dry weight (104.00g) when exposed to salt stress while SUFI recorded the lowest shoot dry weight (33.57g). The main effect of salinity and varieties on root fresh weight indicated significant ($P \leq 0.05$) difference among the various treatments and varieties. The control plants recorded the highest root fresh weight (167.87g), while the lowest (20.24g) root fresh weight was recorded in the highest stress level (10 dS/m). Among the varieties FARO 67 recorded the highest root fresh weight (135.88g) and the lowest root fresh weight was recorded in FARO 44 (60.63g). The effect of salinity and varieties on root dry weight was significant ($P \leq 0.05$) and the highest root dry weight (56.34g) was recorded in the control (0 dS/m), this decreased across the various treatments with the lowest root dry weight (7.19g) recorded in (10 dS/m). FARO 67 was found to have the highest root dry weight (135.88g) while the lowest root dry weight (23.88g) was recorded for FARO 44.

Table 7. Effect of Different Levels of Salinity on Shoot and Root Fresh and Dry Weight of Some Rice Varieties (*Oryza sativa* L.)

SOURCES	SFW	SDW	RFW	RDW
TREATMENTS				
0 dS/m	339.29[a]	119.33[a]	167.87[a]	56.34[a]
4 dS/m	241.60[b]	82.51[b]	120.02[b]	42.82[b]
8 dS/m	129.99[c]	52.42[c]	58.97[c]	19.24[c]
10 dS/m	36.32[d]	11.47[d]	20.24[d]	7.19[d]
LSD	15.048	4.497	7.117	2.790
VARIETIES				
FARO 62	238.19[b]	104.00[a]	105.82[b]	29.39[c]
FARO 44	116.35[cd]	33.11[c]	60.63[e]	23.88[d]
FARO 67	286.17[a]	106.07[a]	135.88[a]	40.47[a]
FARO 57	255.01[b]	86.95[b]	95.35[c]	33.37[b]
SUFI	122.78[c]	33.57[c]	78.52[d]	31.58[bc]
FARARZAIRA	102.29[d]	34.91[c]	74.46[d]	29.70[c]
LSD	18.430	5.508	8.71	3.417
Trt. * Var	**	**	**	**

Figures followed by the same letters along the columns are not significantly different according to Fisher's protected LSD at 5% level. WASA= Weeks after salinity application. **= Significant at 95% level. LSD= least significant difference, Trt= treatment, Var= varieties. SFW= Shoot Fresh Weight, SDW= Shoot dry weight, RFW= Root Fresh Weight, RDW= Root Dry Weight

Treatments and Varieties Interaction on Shoot and Root Fresh and Dry Weight 12 Weeks after Salinity Application.

Table 8 shows the interaction effect of the selected genotypes and the various levels of salinity concentrations on shoot and root fresh and dry weight. The result revealed that FARO 67 recorded the highest shoot fresh weight (543.5g) at 0 dS/m (control). While growth was completely arrested for most varieties at 10 dS/m FARO 44 and FARO 67 had shoot fresh weight of (67.6cm and 160.4) respectively. The interaction between shoot dry weight and varieties was also significant, and highest weight (188.5) was recorded in control of FARO 67.while the weight decreases with increases in salt concentration for all varieties, FARO 44 and 67 which were the surviving varieties at the highest stress level 10 dS/m recorded the least shoot dry weight with (18.93g and 49.90g) respectively.

The result of interaction also revealed that FARO 67 had the highest root fresh weight (222.3g) in control (0 dS/m) while the lowest root fresh weight were observed in the highest salt level 10 dS/m and were recorded in FARO 44 and 67 with (33.7 and 87.8g) respectively. Highest root dry weight was observed in control of FARO 67 and the least root dry weight was observed in FARO 44 and 67 at 10 dS/m.

Table 8: Treatments and Varieties Interaction on Shoot and Root Fresh and Dry Weight 12 Weeks after Salinity Application.

SOURCES			VARIETIES				
	TREATMENTS		FARO 44	FARO 67	FARO 57	SUFI	FARAR ZAIRA
	0 dS/m	358.3^{cd}	177.0^{jk}	543.5^{a}	424.5^{b}	309.9^{e}	222.5^{ghi}
SFW	4 dS/m	248.7^{fg}	136.7l	372.8c	323.5^{de}	181.3^{jk}	186.6^{ijk}
	8 dS/m	195.4^{hij}	84.1^{m}	228.5^{gh}	272.0^{f}	0.00^{n}	0.00^{n}
	10 dS/m	0.00^{n}	67.6^{m}	150.4^{kl}	0.00^{n}	0.00^{n}	0.00^{n}
	0 dS/m	157.2^{b}	48.4^{hi}	188.5^{a}	154.7^{b}	86.4^{fg}	80.9^{g}
SDW	4 dS/m	122.2^{c}	41.07^{i}	123.6^{c}	101.6^{de}	47.87^{hi}	51.8^{h}
	8 dS/m	93.63^{ef}	24.00^{j}	105.30^{d}	91.6^{efg}	0.00^{k}	0.00^{k}
	10 dS/m	0.00^{k}	18.93^{j}	49.90^{hi}	0.00^{k}	0.00^{k}	0.00^{k}
	0 dS/m	188.8^{b}	82.7^{fg}	222.3^{a}	168.2^{c}	175.3^{bc}	169.9^{c}
	4 dS/m	125.5^{de}	70.3^{hi}	141.7^{d}	116.0^{e}	138.8^{d}	127.9^{de}
RFW	8 dS/m	75.4^{gh}	55.9^{i}	125.3^{de}	97.2^{f}	0.00^{k}	0.00^{k}
	10 dS/m	0.00^{k}	33.7^{j}	87.80^{fg}	0.00^{k}	0.00^{k}	0.00^{k}
	0 dS/m	50.2^{c}	32.6^{fg}	71.13^{a}	66.5^{a}	68.03^{a}	49.7^{c}
RDW	4 dS/m	41.27^{de}	29.50^{fg}	44.4^{cd}	35.8^{ef}	58.3^{b}	47.7^{cd}
	8 dS/m	26.7^{gh}	21.7^{h}	35.9^{ef}	31.2^{fg}	0.00^{j}	0.00^{j}
	10 dS/m	0.00^{j}	11.7^{i}	31.43^{fg}	0.00^{j}	0.00^{j}	0.00^{j}

Figures followed by the same letters along the columns are not significantly different according to Fisher's protected LSD at 5% level. SFW= Shoot Fresh Weight, SDW= Shoot dry weight, RFW= Root Fresh Weight, RDW= Root Dry Weight.

DISCUSSION

Standard evaluation score of visual salt injury is a widely used screening technique for salinity tolerance in rice. In the present study, the rice genotypes were classified as moderately tolerant, susceptible, and highly susceptible. Prior to salinity application, plants showed uniformed plant height with respect to varieties as shown in Plate 1. The effect of the different levels of salinity significantly affected plant height of all varieties, the effects increased as the concentration of the stress level increased. For all varieties, plant height was highest at 4dS/m. Plants height significantly reduced with each salt concentration and time of imposition and when concentration was increased to 8dS/m and 10dS/m for 8 and 14 weeks, the stress resulted in plant death. Similar observations in several studies on rice varieties have been reported. Puvanitha *et al*. (2017) witnessed that plants height in rice cultivars reduced significantly when exposed to salt stress compared to the control. Efisue *et al*. (2020) also reported that at 6dS/m the effect of salinity was high and resulted in the decrease of plant height and other growth parameters in rice. The decrease in plant height could be as a result of the disturbance of metabolic processes imposed when osmotic stress reduces water uptake by the roots. Generally salt stress affects crops by osmotic, specific ion, ion imbalance and oxidative damage. Excess Na+ in plants harms cell membrane and organelles of plants and ultimately results in reduction in plant physiological processes leading to plant cell death (Hussain *et al*., 2017).

The amount of chlorophyll in the varieties decreased significantly with increase in salt stress concentration. However, the plants showed almost uniform green colour in the non-stressed condition (control). This decrease could be due to the fact that the stress imposed caused a decrease in the synthesis of the chlorophyll pigment and also caused a high rate of chlorophyll degradation susceptible genotypes exhibited varied symptoms like yellowing of leaves and ultimate death of seedlings at early growth stage. Similar result was reported by Ikhajiagbe *et al*. (2020) who discovered that the leaves of rice plants under stressed conditions exhibited a yellowish white, lethal color, indicating the presence of carotenoid pigment and absence of chlorophyll. Reduced chlorophyll and photosynthetic enzymes like rubisco are the most affected processes of photosynthesis in plants growing under saline condition (Auyo *et al*., 2020). It has been observed that plants have the photosynthetic capacity to adjust and match the conditions they are grown under. However, not all plants have this capacity. The ability of plants to have the high chlorophyll under salt stress may be due to their ability to match/adapt to the stress condition thereby preventing a high rate of chlorophyll degradation and a decrease in the synthesis of chlorophyll pigment. The low amount of chlorophyll recorded in some varieties was attributed to a high rate of chlorophyll degradation characterized by chlorosis as shown in Plate 2, reduced photosynthetic enzymes and low potential for the synthesis of chlorophyll pigment caused by the high amount of Na^+ and Cl^-. This is in agreement with the findings of Hussain *et al*. (2017) who reported that chlorophyll contents in rice leaves are damaged by the addition of Na^+ and Cl^- which might hinder the major electron transport in PSII. Ashrafuzzaman *et al*. (2000) reported that stress significantly reduced the content of total chlorophyll in the leaf and this is attributed to the destruction of chlorophyll a, which is considered to be more sensitive than chlorophyll b. Heidari (2011) also reported that by increasing salinity levels, chlorophyll a and b decreases and this could be as a result of photo inhibition or decrease in chlorophyll content.

Plate 1: Rice plant before salinity application

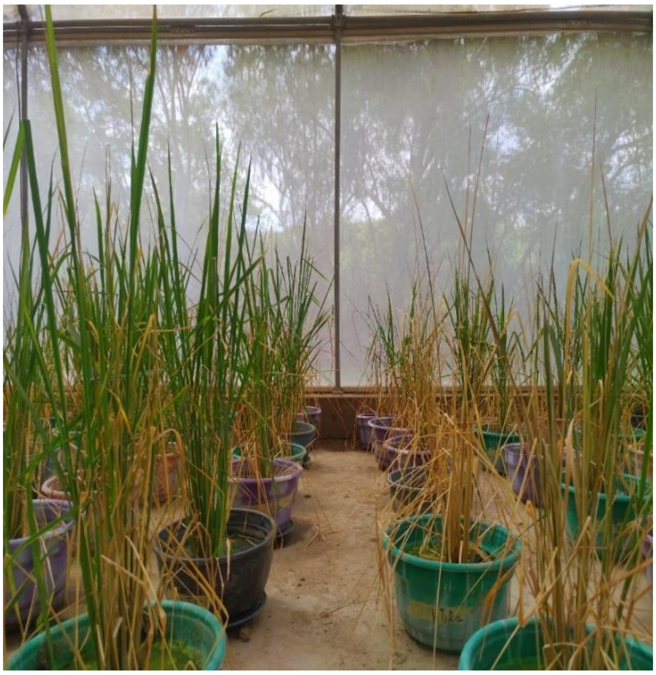

Plate 2: Rice plant after salinity application

Although the biomass varied greatly between the selected genotypes due to varietal differences, as salinity increases, it appeared to have decreased the shoot fresh weight significantly with respect to the control. Shoot fresh weight and dry weight decreased with increase in the level of salt stressed imposed and drastic reduction was found at the highest stress level 10 dS/m. It has been reported that plants, especially those of drought or salt tolerant species have the ability to propagate their roots deeper to absorb more water during osmotic stress (Uyoh *et al*., 2019). The decrease in weight could be because of the osmotic stress imposed by high NaCl concentration which made it difficult for substrate or solute to be moved to the various parts of the plant from the soil, ultimately resulting in limited plant growth and crop productivity. This is in agreement with the findings of Haq *et al*. (2014) who reported significant reduction in shoot fresh and dry weight with increase in salt level and attributed this to the decrease in water potential of rooting medium and growth decline related to osmotic effect under salt stress. Similar result was also reported by Puvanitha *et al*. (2017) who disclosed that salinity significantly reduced shoot dry weight and this may be due to the toxic effects of NaCl and unbalanced nutrient uptake by the plant.

The roots are in direct contact with the surrounding solution. Hence they are the first to encounter the effect of the stress and as a result develop tolerance or get damaged by the salt stress imposed. Root fresh and dry weights were significantly affected by the different levels of salinity. The control plants had the highest root fresh and dry weight and this significantly decreased with each salt concentration from the period of stress imposition to when the experiment was concluded. The reduction of the plant root weight may be due to the osmotic and ionic effect of NaCl imposed on the plants. This result is similar to the finding of Puvanitha *et al*. (2017) who reported that reduction in root weight due to increased salinity may be as a result of a combination of osmotic and specific ion effects of Cl^- and Na^+. Rahman *et al*. (2017) also reported that salt stress (100 mM NaCl 10 dS/m) reduced root length, root dry weight, shoot length and shoot dry weight both in sensitive and in tolerant cultivar where growth reduction is higher in sensitive cultivar compared with tolerant varieties.

CONCLUSION

The study revealed that varietal characteristics and the different concentrations of NaCl negatively affected plant height, leaf chlorophyll content, shoot fresh and dry weight, root fresh and dry weight of rice particularly at the range of 8 to 10 dSm-1 however, two varieties; FARO 44 and FARO 67 exhibited better performance with regards to the parameters measured as they appeared to be the varieties that survived under the highest salinity level (10dSm), hence they were classified as moderately tolerant varieties based on IRRI modified standard evaluation system for rice salinity tolerance. The remaining four varieties; FARO 62, FARO57, SUFI and FARAR ZAIRA were significantly affected by the induced salt stress and were classified as susceptible varieties.

FARO 44 and FARO 67 which performed better under the highest stress level should be subjected to further trial to establish a better level of performance at the studied concentration. More physiological features should be assessed to understand better the effect of toxic ions imposed by salinity stress on the physiology of these plants. Molecular studies should be carried out to identify genes that contribute towards salinity tolerance in rice.

ACKNOWLEDGEMENT

I wish to express my sincere appreciation to the Staff of Plant Biology Department, Agronomy Department, and the Centre for Dry Land Agriculture for their assistance in seeing me conduct this research work successfully.

REFERENCES

Almeida, M. D., Almadanim, M. C., Tiago, Lourenço, T., Abreu, A. I., Saibo, J. M. N. and Oliveira, M. M. (2016). Screening for Abiotic Stress Tolerance in Rice: Salt, Cold, and Drought. *Methods in Molecular Biology*, 1398:155-182

Ashrafuzzaman, M., Khan, M. A. H., Shohidullah, S. M. and Rahman, M. S. (2000). Effect of Salinity on the Chlorophyll Content, Yield and Yield Components of QPM CV. Nutricta. *Pakistan Journal of Biological Sciences,* 3(1): 43-46.

Auyo, M. I., Aliyu, A. and Zakari, M. M. (2021). Effects of Salinity on Yield and Yield Components of Some Varieties of Rice (*Oryza sativa L.*) *Journal of Science Technology and Education*, 9(4):2277-0011.

Efisue, A, A. and Dike, C, C. (2020). Screening Rice (*Oryza sativa. L*) for Salinity Tolerance for Yield and Yield Components in Saline Stressed Environment. *American Journal of Agriculture and Forestry* 8(1): 15-21.

Gregorio, G. B., Senadhira, D. and Mendoza, R.D. (1997). Screening rice for salinity tolerance. *IRRI Discussion Paper Series*, N 22 22.

Haq, U. T., Akhtar, J., Nawaz, S. and Ahmad, R. (2009). Morpho-physiological Response of Rice (*Oryza sativa L.*) Varieties to Salinity Stress. *Pakistan Journal of Botany,* 41(6): 2943-2956,

Heidari, M. (2011). Effect of Salinity Stress on Growth, Chlorophyll Content and Osmotic Components of two Basil (*Ocimum basilicum L.*) Genotypes. 11(2).

Hussain, S., Zhang, J. H., Zhong, C., Zhu, L. F., Cao, X. C., Yu, S. M., Allen, B. J., Hu, J. J. and Jin, Q. Y. (2017). Effects of salt stress on rice growth, development characteristics, and the regulating ways: *Journal of Integrative Agriculture*, 16(11): 2357–2374

Ikhajiagbe, B. and Omoregie, U. E (2020) Growth, yield, genetic parameters and random amplified polymorphic DNA (RAPD) of five rice varieties treated with sodium azide and sown under different saline conditions. *Bulletin of the National Research Centre* 44:89

James, S. D. (2018). Effects of Salinity on Growth and Yield of Rice *(Oryza sativa l.)* and Development of Tolerant Genotypes in Kilosa district, Tanzania. (Unpublished doctoral thesis). Sokoine University of Agriculture Morogoro, Tanzania.

Jamil, M., Charnikhova, T., Houshyani, B., Harro, V.A. and Bouwmeester, J. (2011). Genetic variation in strigolactone production and tillering in rice and its effect on *Striga hermonthica* infection, *Planta,* 235(3): 473–484.

Kargbo, S. S., Showemimo, F. A., Porbeni, J. B. O. and Akintokun P. O. (2019). Response of rice genotypes to salinity under hydroponic conditions. *Journal of Tropical Agriculture, Food, Environment and Extension*, 18(3): 11–18.

Liu, C., Chen ,K., Zhao, X., Wang, X., Shen, C., Zhu, Y., Dai, M., Qiu, X., Yang, R., Xing D., Pang, Y. and Xu, J. (2019). Identification of genes for salt tolerance and yield-related traits in rice plants grown hydroponically and under saline field conditions by genome-wide association study. *Springer Open Journal,* 12(88): 1-13.

Parida, A. K., Das, A. B. and Mohanty, P. (2004). Defense potentials to NaCl in a mangrove, Bruguiera parviflora: differential changes of isoforms of some antioxidative enzymes. *Journal of Plant Physiology*, 161: 531–542.

Puvanitha, S. and Mahendran, S. (2017). Effect of Salinity on Plant Height, Shoot and Root Dry Weight of Selected Rice Cultivars, *Scholars Journal of Agriculture and Veterinary Science*, 4(4):126-131

Qadir, M., Quillérou, E., Nangia, V., Murtaza, G., Singh, M. Thomas, R. J., Drechsel P., and Noble, A. D. (2014). Economics of salt-induced land degradation and restoration. *Natural Resources Forum,* 38: 282–295.

Rahman, A., Kamrun, N., Jubayer, A. M., Mirza, H. M., Shahadat, H. and Masayuki F. (2017) Salt Stress Tolerance in Rice: Emerging Role of Exogenous Phytoprotectants. *Advances in International Rice Research*, PP. 140-174.

Senanayake, R. M. N. H., Herath, H. M. V. G., Wickramesinghe, I. P., Udawela, U. A. K. S. and Sirisena, D. N. (2017). Phenotypic Screening of Rice Varieties for Tolerant to Salt Stress at Seed Germination, Seedling and Maturity Stages. *Tropical Agricultural Research*, 29(1): 90 – 100.

Uyoh E. A., Ntui, V. O., Umego, C., Ita, E. E. and Opara C. (2019). Morphological and molecular screening of rice accessions for salt tolerance. *African Journal of Biotechnology,* 18(27): 612-621.

Zafar, S. A., Shokat, S., Ahmed, H. G. M., Khan, A., Ali, M. Z., and Alif, R. M. (2015). Assessment of salinity tolerance in rice using seedling based morpho-physiological indices. *Advancement in Life Science,* 2(4):142-149